Ion Beam Microfabrication

Manufacturing Technologies

The Manufacturing Science & Technology Center's Focused Ion Beam (FIB) laboratory provides an opportunity for research, development and prototyping. Currently, scientists are developing methods for ion beam sculpting microscale components and devices. This includes shaping of specialty tools such as end-mills, turning tools and indenters. Additionally, staff are developing the capability to sputter predetermined 3-dimensional shapes of various symmetries and periodicities. Two focused gallium ion beam systems are operational. Beam sizes can be varied from 10 nm to 1.5 µm.

Capabilities and Expertise

- Two custom-built focused ion beam systems for precision ion milling;. beam energies are 10-20 keV; target chambers have $1x10^{-7}$ Torr base pressure.
- Gas assisted sputtering with the aid of various chemicals; includes H_2O jet (for gas assisted sputtering of diamond).
- Focused ion beam induced chemical vapor deposition; material can be grown locally onto conductive substrates or layers in a direct-write mode; deposited material includes metals (Au, Cu) or SiOx.
- Techniques for fabricating 3-dimensional shapes such as hemispheres, paraboloids, sine waves of various periodicities, symmetries and sizes.
- Techniques for shaping microtools. (See image 1 for example tools). Tools of single crystal diamond, tungsten carbide, high-speed steel are regularly made for ultra-precision machining; specialty tools, such as indenters, are possible.
- Ability to determine sputter yield and its dependence on incidence angle, dose for almost any material.

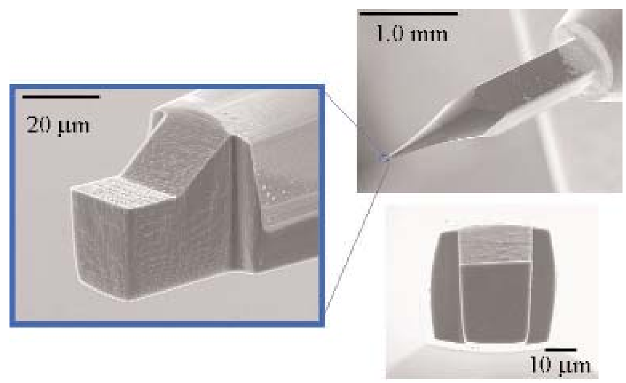

Image 1. Different perspectives of an example turning tool shaped by FIB sputtering. Tool material is single crystal diamond. Diamond is brazed into tungsten carbide mandrel.

Resources

- Two custom-built focused ion beam systems for precision ion milling. Liquid metal gallium ion sources are used in both. System 1 has a single lens column. System 2 has a FEI, dual lens, variable aperture magnum column with CDEM.
- X-y stage with large travel distances. Load lock can accept up to 8” wafers.

National Nuclear Security Administration

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company,for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

Sandia National Laboratories

- Rotation stage for control of ion beam incidence angle. Capable of full rotation through 360°. This also allows for sputtering of small 3-dimensional substrates such as tubes. (See image 2 of coil made by atomic beam lathe process).

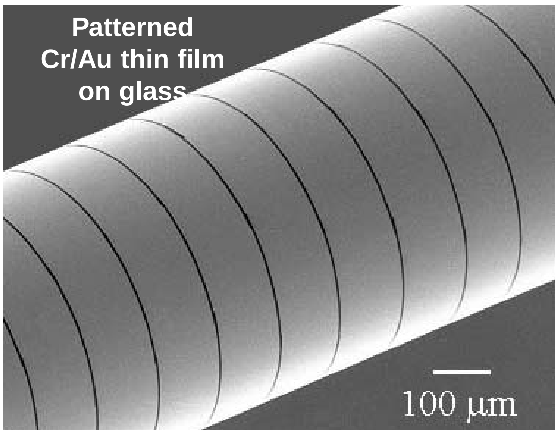

Image 2. FIB sputtered microcoil made using an atomic beam lathe process. Regions that appear dark have been bombarded to remove a Cr/Au thin film from a glass tube substrate.

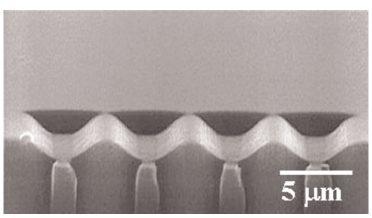

Image 3. Example sine wave FIB sputtered into initially planar Si substrate.

Accomplishments

- Developed techniques for shaping micro-cutting tools with the focused ion beam. Techniques establish a cutting edge radius of curvature equal to 40 nanometers as evidenced by transmission electron microscopy.
- Developed techniques for ion shaping predetermined, 3-dimensional shapes.
- Shaped target materials for LLNL/NIF high-density plasma experiments.
- Developed improved understanding of ion beam induced effects on yield, morphology and microstructure.
- Developing yield database for high energy sputtering. Yield is determined as a function of ion beam incidence angle to 89°.

Contact

David Adams, (505) 844-8317
dpadams@sandia.gov

Michael Vasile, (505) 844-1858
mjvasil@sandia.gov

SAND2003-3271P